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A longitudinal study on the relationship between temperature rhythms and lifestyle in children

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Abstract

In order to clarify the long-term influence of lifestyle factors, body temperature and lifestyle conditions were studied over 8 months from May 2007 to December 2007 on all days, excluding Saturdays and Sundays and national holidays, for 64 children in nursery school from the ages of 1–5. The mean time of the going to sleep was 21:34 and the mean time of waking up was 6:48. The time of waking up was significantly later in the period from October to December than that in the period from May to September, however, no seasonal differences were observed in the time of going to sleep. The body temperature rhythm was entrained in approximately 50% of children, and four to five-year-old children have a higher proportion of entrained body temperature rhythms than one to three-year-old children. The factors related to body temperature rhythms were the "change in time of going to sleep", "regularity of lifestyle", and "time of going to sleep in December". The strongest relationship was found in "change in time of going to sleep".

Key words

children, temperature rhythm, sleep-wake rhythm, lifestyle, longitudinal study

Introduction

In recent years, there have been many reports that environmental changes influence the bodies and minds of children[1-5]. In particular, it has been reported that nocturnal lifestyles suppress the secretion of melatonin[6], causing children to remain in a chronically jet-lagged state, which interferes with the normal development process of biological rhythms[7]. Additionally, irregularities in the sleep-wake cycle due to nocturnal lifestyles suppress children's increases in body temperature during the day and lowers activity levels[4]. Furthermore, the low antioxidant effect caused by insufficient melatonin secretion increases the cancer rate and may be one cause of premature puberty[7].

This kind of nocturnal lifestyle suppresses the normal function of biological rhythms and causes children to have health problems. There have been many reports, particularly in the area of school health and children's health, in terms of endocrinal and autonomic abnormalities in children[8-10]. In addition, there have been many reports suggesting the potential for these abnormalities lead to mental problems, such as children not attending school or locking themselves in their rooms (*hikikomori*)[11,12].

However, most reports deal with primary to high school students who present problems of the mind and body from the influence of the abnormalities. Reports on infants during the formation of biological rhythms are limited to reporting the actual circumstances[13-16], and there are few studies investigating infant lifestyles in relation to the formation of biological rhythms.

In terms of longitudinal studies investigating

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children's lifestyle habits, there have been large-scale cohort studies that use questionnaires at infant health checks as follow-up related to children's lifestyle habits[17-19]. However, these are not long-term continuous studies of the changes in lifestyle and, therefore, these studies do not sufficiently cover the actual status and circumstances. In relation to biological rhythms in recent years, there have been follow-up studies[20,21,22] comparing sleep-wake rhythms from the fetal period or neonatal period relative to the lifestyle habits of the mother and circumstances of the birth, and there have been reports from a longitudinal study investigating the body temperature rhythms of three children measured three times per year.[23,24] However, there have been few studies like the present one investigating children's body temperatures and lifestyle habits over long periods of time.

Consequently, we conducted longitudinal research on children's body temperatures, the cortisol in their saliva, and their lifestyle habits in 2002, 2003, and 2004[25,26] in order to clarify the influence on children's biological rhythms. The results showed that there is a relationship between temperature and serum cortisol and lifestyle habits[26], and the time of going to sleep is strongly related to children's temperature rhythms[25]. However, as these studies[25,26] was carried out over a limited timeframe of 5 days, the relationship between body temperature rhythms and lifestyle factors at certain points in time were clarified but it was not possible to address the long-term influence of these factors.

The present study involved an 8-month follow up of children's body temperature rhythms and lifestyle factors related to the rhythms so as to clarify the long-term influence of the relevant factors identified in the previous study with regard to body temperature rhythms.

Methods

1. Subjects

The subjects of this study are 113 infants aged 1 to 5 years old who commute to nursery schools within prefecture A, and these subjects were selected by means of snowball sampling. Children who were ill, premature infants, or children with disabilities that were considered to have an influence on body temperature rhythms were excluded from the analysis.

2. Study design

1) Body temperature measurements

Body temperature and lifestyle conditions were examined every day from May to December 2007, excluding Saturdays and Sundays and national holidays. Body temperature was measured five times per day. Measurements were carried out using an Omron MC-106B digital thermometer (non-predictive type) and were taken under the armpit. The measuring method corresponds with that which was used in the prior study[26]. For measurement times, the time periods that were beneficial for rhythm determination and did not interfere with the children's daily activities were selected from the times used in the prior study. The times were as follows: at wake up time, when attending the nursery (9 a.m.), before lunch (11 a.m.), upon leaving the nursery (4 p.m.), and when going to sleep. Measurements taken at wake up time and when going to sleep were performed by the child's parents, while measurements taken when attending the nursery, before lunch and upon leaving the nursery were performed by a team of 20 nursery staffs and two nursery nurses. All measurements were recorded along with the time. The concordance rate between all assessors – nursery staff, nursery nurses and parents – has not been calculated, but sufficient practice was conducted after advance explanations of the measurement method. Furthermore, it was established that measurements indicating body temperatures to be lower than 36.0℃ or higher than 37.5℃ would be retaken, and that the handling of measured values would exclude and classify as outliers any data recorded on days of poor health or data obviously subject to measurement error.

2) Lifestyle conditions

In terms of the sleep condition, the time the children woke up and went to sleep was examined, and from the results, their lengths of nighttime sleep were calculated. As for naps, nursery school

policy dictates that children of ages 3 and younger take naps, while in response to their conditions those who are aged 4 or older gradually stop taking naps from September through to December. Furthermore, breakfast intake is categorized and reported on using 3 different levels: "ate well," "ate a little," and "did not eat."

3) Attributes

Dates of birth were obtained from the nursery school records, which were used to calculate ages in years or months during the study period. Additionally, the following items were recorded: gender, family structure, birth-related environment, developmental environment up to the present, and the general health condition. In addition, nursery school teachers were interviewed on the parents' child-rearing attitudes.

3. Definition of terms

Entrainment is the state whereby biological rhythms with different cycles maintain their appropriate rhythms by entrainment factors and function to maintain the homeostasis of the body by influencing each other[27]. In the present study, we used this concept mainly for body temperature rhythms and thus defined entrainment as the matching of an individual's body temperature rhythm and sleep-wake cycle, there being a regular rising and falling of body temperature during the day. Desynchronization is defined as the non-matching of an individual's sleep-wake cycle and body temperature rhythm, with little fluctuations in body temperature during a given day.

4. Methods of analysis

1) Categorization of body temperature rhythms

The body temperature measurements in each time slot were expressed against a monthly average body temperature and the monthly body temperature rhythms of each individual were then determined according to the extent of daily changes in body temperature. The criteria of the previous study[26] were adopted for the criteria of determination in this study. Those rhythms that satisfy all criteria were categorized as entrainment and the rest were categorized as desynchronization.

2) Lifestyle factors

(1) Calculation of monthly sleep averages

After visually confirming daily changes in individual times of going to sleep, time of waking up, and length of nighttime sleep via graphs, monthly averages were calculated.

(2) Long-term lifestyle factors

i) Changes in sleep conditions

Changes in sleep conditions of each individual from May to November were determined as follows: In regard to changes in time of going to sleep, after obtaining monthly averages of the time of going to sleep, each month was categorized into a "Good" group and a "Poor" group based on the overall mean + 0.5 SD for time of going to sleep. The two groups were then further categorized into the following three groups: a "Good" group comprising subjects reporting appropriate time of going to sleep throughout the period from May to November; an "Unstable" group comprising subjects reporting both appropriate and inappropriate time of going to sleep; and a "Poor" group comprising subjects reporting consistently inappropriate time of going to sleep throughout the period.

In regard to time of waking up, each subject was categorized into a "Good" group and a "Poor" group according to average time of waking up for each month. Then the two groups were further categorized into the above-mentioned three groups: a "Good" group comprising subjects reporting appropriate time of waking up throughout the period from May to November; an "Unstable" group comprising subjects reporting both appropriate and inappropriate time of waking up; and a "Poor" group comprising subjects reporting consistently inappropriate time of waking up throughout the period.

In regard to changes in the length of nighttime sleep, the average of length of nighttime sleep in each month was categorized into a "Long" group and a "Short" group based on an overall mean − 0.5 SD for the length of nighttime sleep. Then the two groups were further categorized into the above-mentioned three groups: a "Good" group comprising subjects reporting an appropriate length of nighttime sleep throughout the period

from May to November; an "Unstable" group comprising subjects reporting both appropriate and inappropriate length of nighttime sleep; and a "Poor" group comprising subjects reporting consistently inappropriate length of nighttime sleep throughout the period.

ii) Regularity of lifestyle

The regularity of lifestyle was determined according to the time of going to sleep, which was found in the previous study[26] to be most closely related to the body temperature rhythms and which varied greatly with each individual. After visually confirming monthly changes in the time of going to sleep of each individual, the subjects were categorized into the "Irregular" group comprising those who showed that the time of going to sleep change over 2 hours five times or more in a month and the "Regular" group comprising those with less than five times. Then after confirming monthly changes in regularity of each individual, they were further categorized into the following three groups: the "Good" group comprising those who consistently showed regularity throughout the period from May to November; the "Unstable" group comprising those who showed both regularity and irregularity; and the "Poor" group comprising those who consistently showed irregularity throughout the period.

(3) Short-term lifestyle factors

The average time of going to sleep, the average time of waking up, the average length of nighttime sleep, and the intake of breakfast were set as short-term factors since the body temperature rhythms of December, the last month of this study, had been set as a response variable.

3) Methods of analysis

An unpaired t-test was used for comparison of body temperature, hours of sleep, and age in month by body temperature rhythms, whereas a paired t-test was used for their monthly comparison and the Mann-Whitney U-test was used for the comparison of the intake of breakfast by body temperature rhythms. For the comparison of proportion of the intake of breakfast, changes in hours of sleep, and the regularity in daily life, an x^2-test was used. After confirming the body temperature rhythms and relationships among variables by month, a multiple logistic regression analysis was performed with the body temperature rhythms of the last month (December) as a response variable and the items in the lifestyle factors and attributes, which showed significant difference, as independent variables. For long-term influence factors in lifestyle factors, that is, factors that have contributed to the changes in sleep conditions from May to November, changes in the time of going to sleep, the time of waking up, and length of nighttime sleep and the regularity of lifestyle were used. For short-term influence factors, the average time of going to sleep, the average time of waking up, the average length of nighttime sleep, and the intake of breakfast in December were used.

For data analysis, statistics software JMP7.0.1, SPSS17.0J, and EXCEL Statistics 5.0 were used.

5. Ethical considerations

This study was approved by the ethics committee of Kanazawa University under approval number: Ho no. 126. To conduct this study, after obtaining approval from principals of nursery schools, the information sheet and consent form were distributed to parents, and the explanation of the study was carried out. The information sheet explained the purpose and methodology of the study, clearly stated that participation in the study was voluntary and that it was possible to refuse participation or withdraw from the study, and there would be no disadvantage in terms of the care of the child in the nursery school for refusal to participate or withdrawal in the middle of the study. In addition, it was explained that personal information would be handled and privacy would be protected, and the results of the study would not be used for any purpose other than for the study itself. The study was carried out for subjects who consented after receiving an explanation of the above steps.

Results

1. Subjects' attributes (Table 1)

Of the 113 nursery school children, 64 were taken as subjects for analysis after removing 49 for

Table 1. Attributes of subjects (n = 64)

Attributes		
Age in months (In December)		48.75 ± 16.41
Age	1 Yr	11 (17.2)
Number (%)	2 Yr	14 (21.9)
	3 Yr	13 (20.3)
	4 Yr	21 (32.8)
	5 Yr	5 (7.8)
Sex	Male	34 (53.1)
Number (%)	Female	30 (46.9)

whom body temperature measurements at home were not continued. The mean ± SD of age in December was 49 ± 16 months (range: 17–79 months), the number of children with ages were 11 (17.2%) in one-year-olds, 14 (21.9%) in two-year-olds, 13 (20.3%) in three-year-olds, 21 (32.8%) in four-year-olds, and 5 (7.8%) in five-year-olds. In regards to gender, 34 (53.1%) of the children were male and 30 (46.9%) were female.

2. The observed monthly lifestyle

1) Sleep conditions (Table 2)

The overall mean ± SD for time of waking up was 6:48 ± 32 minutes, the overall mean ± SD for time of going to sleep was 21:34 ± 34 minutes, and the overall mean ± SD for length of nighttime sleep were 9.2 ± 0.6 hours. No differences were seen according to age for any of time of waking up, time of going to sleep, and length of nighttime sleep. The mean for each month is shown in the table 2. When monthly mean time was compared, significant differences were seen in time of waking up where October, November, and December were later than May, June, July, August, and September. Significant differences were also seen in night sleeping hours, where the hours of sleep in May were shorter than October; those in June were shorter than September, October, November, and December; those in July were shorter than in October and November; and those in August were shorter than in September, October, November, and December. Almost no differences were seen for times of going to sleep with months.

2) Breakfast intake conditions

In regard to breakfast intake conditions, in all months, less than 30% of the children "ate well" and less than 5% of the children "did not eat" breakfast at all.

3. The changes in lifestyle conditions (Table 3)

1) The changes in sleep-style conditions

Regarding the change in sleep conditions, the number of subjects and proportion for each group is shown in the table 3. For the change in time of waking up, 36 (56.3%) were in the "Good" group, 21 (32.8%) were in the "Unstable" group, and 7 (10.9%) were in the "Poor" group. For the changes in time of going to sleep, 21 (32.8%) were in the

Table 2. The observed monthly sleep conditions (n = 64)

Month	Time of waking up	Time of going to sleep	Length of nighttime sleep
May	6:44 ± 34[a)]	21:34 ± 33[f)]	9.18 ± 0.52[g)]
June	6:43 ± 32[b)]	21:38 ± 37	9.08 ± 0.55[h)]
July	6:44 ± 32[c)]	21:36 ± 34	9.15 ± 0.57[i)]
August	6:43 ± 34[d)]	21:37 ± 33	9.12 ± 0.57[j)]
September	6:47 ± 30[e)]	21:32 ± 35	9.25 ± 0.57
October	6:54 ± 32	21:33 ± 35	9.35 ± 0.57
November	6:56 ± 31	21:35 ± 34	9.33 ± 0.58
December	6:56 ± 32	21:38 ± 34	9.32 ± 0.62
Overall mean	6:48 ± 32	21:34 ± 34	9.22 ± 0.57

For comparisons between months a paired t-test was used.
a) $p<.01$ between May and October, November, December
b) $p<.001$ between June and October, November, December, $p<.05$ between June and September
c) $p<.01$ between July and October, November, December
d) $p<.01$ between August and October, November, December
e) $p<.01$ between September and October, November, December
f) $p<.05$ between May and June, August
g) $p<.05$ between May and October
h) $p<.001$ between June and October, $p<.01$ between June and November, December, $p<.05$ between June and September
i) $p<.01$ between July and October, $p<.05$ between July and November
j) $p<.001$ between August and October, $p<.01$ between August and November, December, $p<.05$ between August and September

Table 3. The changes in sleep-style conditions (n = 64)

	Good	Unstable	Poor
Time of waking up	36 (56.3)	21 (32.8)	7 (10.9)
Time of going to sleep	21 (32.8)	31 (48.4)	12 (18.8)
Length of nighttime sleep	29 (45.3)	27 (42.2)	8 (12.5)
Regularity of lifestyle	21 (32.8)	34 (53.1)	9 (14.1)

"Good" group, 31 (48.4%) were in the "Unstable" group, and 12 (18.8%) were in the "Poor" group. For night sleeping hours, 29 (45.3%) were in the "Good" group, 27 (42.2%) were in the "Unstable" group, and 8 (12.5%) were in the "Poor" group.

2) Regularity of lifestyle.

Regarding the regularity of lifestyle, 21 (32.8%) were in the "Good" group, 34 (53.1%) were in the "Unstable" group, and 9 (14.1%) were in the "Poor" group.

3) The changes in breakfast intake conditions

Almost no individual fluctuations were seen regarding breakfast intake conditions. (date not shown)

4. Body temperature rhythm in each month and relevant factors (Table 4)

Individual body temperature rhythms were

Table 4. Temperature rhythm in each month and related factors

Month	Factor	Temperature rhythm		Comparison between temperature rhythm
		Entrainment	Desynchronization	P value
May (n = 58)	N (%)	24 (41.4)	34 (58.6)	
	Age in months	44.76 ± 17.95	40.63 ± 16.38	0.277 ns
	The time of waking up	6:34 ± 32	6:52 ± 34	0.025 *
	Time of going to sleep	21:16 ± 20	21:46 ± 35	<0.001 ***
	Length of nighttime sleep	9.30 ± 0.52	9.01 ± 0.50	0.185 ns
June (n = 58)	N (%)	26 (44.8)	32 (55.2)	
	Age in months	46.92 ± 15.51	40.62 ± 17.84	3.222 ns
	The time of waking up	6:37 ± 30	6:47 ± 33	0.111 ns
	Time of going to sleep	21:22 ± 28	21:50 ± 38	0.001 **
	Length of nighttime sleep	9.27 ± 0.53	8.97 ± 0.53	0.048 *
July (n = 61)	N (%)	28 (45.9)	33 (54.1)	
	Age in months	47.86 ± 14.61	40.26 ± 18.17	0.172 ns
	The time of waking up	6:43 ± 31	6:46 ± 32	0.346 ns
	Time of going to sleep	21:21 ± 19	21:49 ± 39	0.001 **
	Length of nighttime sleep	9.37 ± 0.48	8.98 ± 0.58	0.019 *
August (n = 61)	N (%)	34 (55.7)	27 (44.3)	
	Age in months	49.62 ± 13.81	38.79 ± 18.68	0.035 *
	The time of waking up	6:43 ± 32	6:44 ± 37	0.621 ns
	Time of going to sleep	21:26 ± 25	21:50 ± 37	0.002 **
	Length of nighttime sleep	9.28 ± 0.48	8.88 ± 0.58	0.011 *
September (n = 64)	N (%)	37 (57.8)	27 (42.2)	
	Age in months	47.38 ± 15.21	40.13 ± 19.93	0.357 ns
	The time of waking up	6:41 ± 28	6:55 ± 32	0.038 *
	Time of going to sleep	21:19 ± 24	21:49 ± 41	<0.001 ***
	Length of nighttime sleep	9.37 ± 0.52	9.01 ± 0.60	0.049 *
October (n = 64)	N (%)	36 (56.2)	28 (43.8)	
	Age in months	50.83 ± 13.92	37.84 ± 18.81	0.028 *
	The time of waking up	6:47 ± 26	7:02 ± 37	0.069 ns
	Time of going to sleep	21:20 ± 21	21:47 ± 47	0.002 **
	Length of nighttime sleep	9.43 ± 0.47	9.23 ± 0.65	0.129 ns
November (n = 64)	N (%)	33 (52.4)	30 (47.6)	
	Age in months	49.48 ± 16.59	41.97 ± 17.89	0.387 ns
	The time of waking up	6:48 ± 26	7:04 ± 33	0.068 ns
	Time of going to sleep	21:16 ± 18	21:55 ± 35	<0.001 ***
	Length of nighttime sleep	9.53 ± 0.50	9.15 ± 0.62	0.003 **
December (n = 64)	N (%)	31 (48.4)	33 (51.6)	
	Age in months	53.32 ± 14.61	44.45 ± 17.06	0.030 *
	The time of waking up	6:49 ± 28	7:02 ± 34	0.108 ns
	Time of going to sleep	21:20 ± 18	21:56 ± 38	<0.001 ***
	Length of nighttime sleep	9.48 ± 0.59	9.09 ± 0.55	0.009 **

For comparisons between temperature rhythm, a non paired t-test was used.
Triple asterisks (***) indicate $p<.001$, double asterisks (**) indicate $p<.01$, and single asterisks (*) indicate $p<.05$, ns indicate not significant

determined for each month. The months which lacked sufficient values to determine the body temperature rhythm were excluded from the analysis. As a result, the entrainment of body temperature rhythm for each month was observed for 24 (41.4%) children in May, 26 (44.8%) children in June, 28 (45.9%) children in July, 34 (55.7%) children in August, 37 (57.8%) children in September, 36 (56.2%) children in October, 33 (52.4%) children in November, and 31 (48.4%) children in December. The higher proportion of entrainment was found in August, September and November.

The relationship between body temperature rhythms and relevant factors was checked for each month. The factors that were related were different somewhat each month. However, the time of going to sleep had a strong relationship to body temperature rhythms in all months. A relationship was seen with time of waking up in May and September, and a relationship was seen with length of nighttime sleep from June to September, November, and December.

5. Factors related to body temperature rhythms

In order to investigate the long-term influence of lifestyle habits during infancy on body temperature rhythms, an analysis was conducted with body temperatures in December, which was the final month of the 8-month study, as the response variable. For explanatory variables, the changes in time of going to sleep and waking up, in length of nighttime sleep, and lifestyle regularity were used as long-term relevant factors. Since no changes were observed across the 8 months in the breakfast intake conditions for each subject, this factor was not included in the long-term relevant factors. As short-term relevant factors, time of waking up, time of going to sleep, length of

Table 5. Body temperature rhythms and related factors

Factor		Temperature rhythm		Comparison between temperature rhythm
		Entrainment (n = 31)	Desynchronization (n = 33)	P value
Attributes				
Mean age in months		53.3 ± 14.6	44.5 ± 17.1	0.030 *
Age of 1-3year		13 (34.2)	25 (65.8)	0.010 **
Age of 4-5year		18 (69.2)	8 (30.8)	
Long-term related factors				
Change in time of waking up	Good	22 (61.1)	14 (38.9)	0.039 *
	Unstable	8 (38.1)	13 (61.9)	
	Poor	1 (14.3)	6 (85.7)	
Changes in time of going to sleep	Good	19 (90.5)	2 (9.5)	<0.001 ***
	Unstable	9 (29.0)	22 (71.0)	
	Poor	3 (25.0)	9 (75.0)	
Changes in length of nighttime sleep	Good	15 (51.7)	14 (48.3)	0.858 ns
	Unstable	12 (44.4)	15 (55.5)	
	Poor	4 (50.0)	4 (50.0)	
Regularity of lifestyle	Good	13 (61.9)	8 (38.1)	0.037 *
	Unstable	17 (50.0)	17 (50.0)	
	Poor	1 (11.1)	8 (88.9)	
Short-term related factors				
Time of waking up in December		6:49 ± 28	7:02 ± 34	0.108 ns
Time of going to sleep in December		21:20 ± 18	21:56 ± 38	<0.001 ***
Length of nighttime sleep in December		9.48 ± 0.59	9.09 ± 0.55	0.009 **
Breakfast inkake conditions in December	Good	11 (61.1)	7 (38.9)	0.418 ns
	Unstable	19 (44.2)	24 (55.8)	
	Poor	1 (33.3)	2 (66.7)	

For the comparison of mean for each body temperature rhythm, non paired t-test was used, and a χ^2 test was used for the comparison of proportions

Triple asterisks (***) indicate $p<.001$, double asterisks (**) indicate $p<.01$, single asterisks (*) indicate $p<.05$, ns indicate not significant

nighttime sleep, and breakfast environment in December were used. After checking the relationship between variables and selecting the independent variables, the factors were adjusted and a multiple logistic regression analysis was carried out.

1) Body temperature rhythms and relevant factors (Table 5)

Regarding the body temperature rhythms for the final month, 31 (48.4%) children were included in the entrainment group and 33 (51.6%) children were included in the desynchronized group. The proportion of children in the entrainment group was higher for four to five-year-olds compared to one to three-year-olds. Regarding the relationship between body temperature rhythm and other factors, significant differences were observed for change in time of waking up and time of going to sleep, regularity of lifestyle, time of going to sleep in December, length of nighttime sleep in December, age in months, and age in years.

2) Relationship of body temperature rhythm with relevant factors (Table 6)

The response variable was body temperature rhythm. The independent variables were change in time of going to sleep, change in length of nighttime sleep, regularity of lifestyle, time of going to sleep in December, length of nighttime sleep in December, and age in years, which were found to have significant differences, as well as breakfast environment in December, which had *p*-values close to 0.05. The factors were adjusted by the stepwise method (cut-off point: p = 0.25). A multiple logistic regression analysis was carried out on the adopted factors, which were the explanatory variables of change in time of going to sleep, regularity of lifestyle, time of going to sleep in December, age in years, and breakfast environment in December. The results showed significant differences in change in time of going to sleep, regularity of lifestyle, and time of going to sleep in December. The strongest relationship was observed for change in time of going to sleep, which made clear that the body temperature rhythm is strongly influenced by continuous lifestyle habits.

Discussion

In this study, the mean time of going to sleep for all children was 21:30 and the mean waking time was around 6:50. Both of these times were approximately 30 minutes earlier than the results of the study conducted in 2002[25-26] where the time of going to sleep was approximately 22:00 and the wake up time was approximately 7:20. This agreed with the results of a study by the Ministry of Health, Labor, and Welfare that there was an increasing proportion of children who went to sleep before 22:00 and who woke up before 8:00[28]. One of the reasons for this is thought to be that there is a heightened awareness and understanding among the general public of children's lifestyles, such as the start of the National Council of "Hayane Hayaoki Asagohan" ("Sleep early, wake early, have breakfast") in 2006.

On the other hand, the present study found that children's lifestyle habits are very unstable. Many studies of children's lifestyle habits have focused on cross-sectional investigations[17-19]. However, the present study investigated the sleep conditions of individuals over a period of 8 months. While 30% of subjects had consistently early times of going to

Table 6. Relationship of body temperature rhythm with relevant factors

(n = 64)

Factor		OR	95%CI for OR	P-value
Age	1,2,3Yr-4,5Yr	2.087	0.926-5.200	p=0.076
Long-term related factors				
Changes in time of going to sleep	Good-Unstable&Poor	0.196	0.143-0.520	p=0.0005 ***
Regularity of lifestyle	Good-Unstable&Poor	0.220	0.033-0.801	p=0.021 *
Short-term related factors				
Time of going to sleep in December		9.050	1.771-67.343	p=0.0066 **
Breakfast inkake conditions in December	Good-Unstable&Poor	1.796	0.823-4.195	p=0.142

Note: Logistic regression analysis. Nagelkerke R^2=0.51. The dependent variables are the body temperature rhythms: entrainment=1, desynchronization=0. OR,odds ratio; Cl,confidence interval.

sleep over these 8 months, 20% were consistently late sleeping and the remaining half had a mixture of early months and late months. Additionally, half of the subjects had an irregular lifestyle where there was a mixture of early sleeping and late sleeping days within a given month. These results suggest that a lifestyle of early sleeping and early waking up has not settled among children and may highlight lifestyle habit issues in childhood, which is not readily clear using cross-sectional studies alone.

We have used time of going to sleep, which has been found to have the strongest relationship with body temperature rhythms in the prior study[26], as a long-term factor in relation to body temperature rhythm, and this was achieved by assessing the lifestyle habits over 8 months from the point of view of the changes and regularity of time of going to sleep. As a result, the factor that had a strongest influence on the final body temperature rhythms was the change in time of going to sleep, which shows that continual lifestyle habits had a long-term influence of body temperature rhythms. This long-term effect can increase with longer periods and with younger ages.

Similarly, the regularity of lifestyles had a strong influence on body temperature rhythms. The present study found that children's lifestyle habits are very unstable. However, considering that adults' lifestyles are run by a one-week social life cycle, it could be that children's body health cycles may be repeating fatigue and recovery in units of one week. Having an early lifestyle on weekdays and a late one on holidays to fit the convenience of parents, who accumulate fatigue on Mondays, may seem normal and adequate on weekdays; however, the possibility of it having an influence on children's bodies and minds in the long term development process cannot be ruled out. Since all children's lifestyles are dependent upon parents and other adults, parents need to be clearly aware that it is important for them to adjust children's habits in order to improve their lifestyles. We have not carried out a detailed study of the factors leading to irregular times of going to sleep; however, further investigation is required in the future in order to improve children's lifestyle habits.

On the other hand, when observing the overall the changes in sleep conditions across 8 months, the time of waking up in the period from October to December was significantly later than that in the period from May to September. We consider this to be a result of the differences in the hours of sunlight due to seasonal changes. There are many reports of delayed time of waking up during wintertime for adults[29], and it is suggested that children grow with the influences of adult lifestyle habits. As nursery schools have a set attendance time and many mothers go to work, the waking up time of children who attend nursery schools is thought to be relatively stable overall, and fluctuations in time of waking up across days are smaller than those of times of going to sleep[25]. It is interesting that the results of this 8-month study show that the sleep-wake cycle of children is influenced by the seasonal changes. On the other hand, almost no difference was seen in the time of going to sleep between months. This shows that time of going to sleep is more strongly influence by the man-made environment for children rather than by the natural biological rhythms of humans. As many reports are available on the vicious cycle of lifestyle habits being caused by time of going to sleep[25,30-32], we consider the time of going to sleep to be a useful indicator of the realistic quality of the child-raising environment.

In the present study for four-year-olds transferred to monophasic sleep where the child no longer naps during the afternoon during the months of September-December. Therefore, the absence of afternoon naps can be considered to be one of the factors influencing an earlier time of going to sleep. Motegi et al. argue in their study[33] with four to six-year-old children as subjects, that afternoon naps of at least 1-hour has an impact on nighttime sleep, and that if an afternoon nap causes a delay in the time of going to sleep, there is a need to review how the afternoon nap is taken and to switch lifestyle habits so that a monophasic sleep pattern can be acquired. In the present study, we have not examined the amount of time and timing of afternoon naps; however, for children who have

later times of going to sleep due to not being able to fall asleep, no longer taking naps at an early stage may be a beneficial measure for an improvement in lifestyle circumstances, and we would like to make this a subject of future study.

In order to provide a more precise evaluation of the measurement, further study is required to take into consideration environmental factors, for example temperature and humidity, as well as the activity level of children.

Limitations of the study

This study was carried out for the purpose of clarifying the long-term influence of lifestyle factors on body temperature rhythms by examining changes during the period of eight months from May to December. However, the targets of this study were the children experiencing rapid development and the period of eight months was not sufficient for the survey. Furthermore, results showed that there are seasonal differences in lifestyle depending on the time of survey. Therefore, it is desirable to continue the survey for a one-year period. In order to define the influence of lifestyle factors during the process of forming body temperature rhythms, further follow-up studies on children are required.

Since priority was given to longitudinal study for eight months, lifestyle factors were limited to sleep and meals. Consequently, other factors that may affect body temperature, such as the amount of activity and temperature, were not investigated in this study and their potential impact on the results cannot be specified. For the sleep conditions, since descriptions by parents were used, the accuracy in recording hours and clock time is very limited compared to actigraph records. Other limitations of this study include the possibility of analyzers being cooperative parents and the small number of target children due to the many dropouts.

Conclusion

In order to clarify the long-term influence of lifestyle factors, body temperature and lifestyle conditions were studied over 8 months from May 2007 to December 2007 on all days, excluding Saturdays and Sundays and national holidays, for 64 children in nursery school from the ages of 1－5. The mean time of the going to sleep was 21：34 and the mean time of waking up was 6：48. The time of waking up was significantly later in the period from October to December than that in the period from May to September, however, no seasonal differences were observed in the time of going to sleep. The body temperature rhythm was entrained in approximately 50% of children, and four to five-year-old children have a higher proportion of entrained body temperature rhythms than one to three-year-old children. The factors related to body temperature rhythms were the "change in time of going to sleep", "regularity of lifestyle", and "time of going to sleep in December". The strongest relationship was found in "change in time of going to sleep".

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子どもの体温リズムと生活習慣に関する縦断的研究

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要　　旨

１～５歳の保育園児64名を対象に、土日、祝日を除く2007年５月から12月までの８ヶ月間、体温と生活状況を調査し、幼児の体温リズムと長期的な生活要因の関連を明らかにした。幼児の平均就寝時刻は21時34分、平均起床時刻は６時48分であった。起床時刻は５～９月に比べ10～12月では有意に遅くなっていたが、就寝時刻には時期による差は見られなかった。体温リズムが同調していた子どもは約５割で、１～３歳に比べ４～５歳では同調群の割合が高くなっていた。体温リズムと関連が認められたのは「就寝時刻の推移」、「生活の規則性」、「12月の就寝時刻」で、最も強い関連があったのは「就寝時刻の推移」であった。